DREDGED MATERIAL RESEARCH PROGRAM

CONTRACT REPORT D-77-3

RECENT AND PLANNED MARSH ESTABLISHMENT WORK THROUGHOUT THE CONTIGUOUS UNITED STATES A SURVEY AND BASIC GUIDELINES

by

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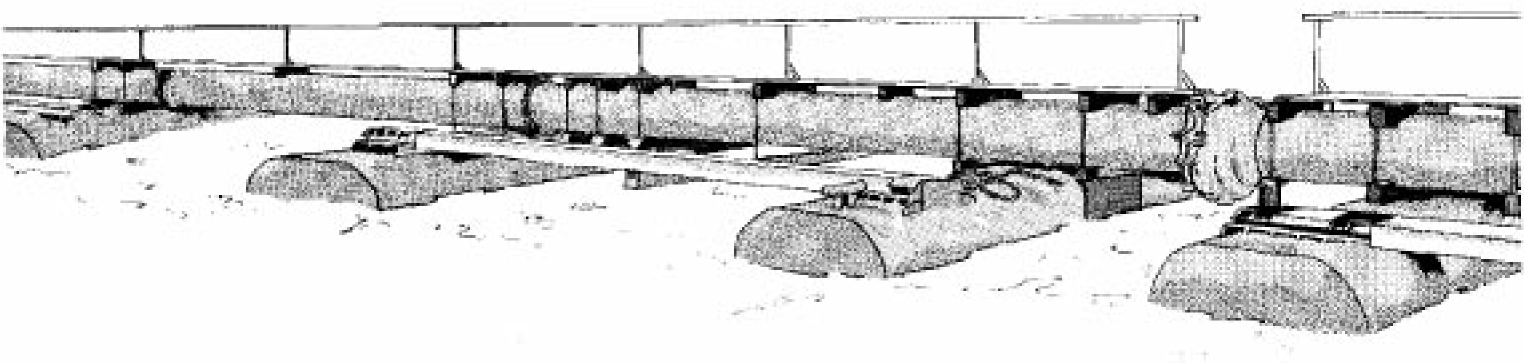
Final Report



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Under Purchase Order No. DACW39-75-M-4215
(DMRP Work Unit 4A25)

Monitored by Environmental Effects Laboratory
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

DEPARTMENT OF THE ARMY
WATERWAYS EXPERIMENT STATION, CORPS OF ENGINEERS
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IN REPLY REFER TO: WESYV 29 April 1977

SUBJECT: Transmittal of Contract Report D-77-3

TO: All Report Recipients

1. The contract report transmitted herewith represents the results of one of a series of research efforts (work units) undertaken as part of Task 4A (Marsh Development) of the Corps of Engineers' Dredged Material Research Program (DMRP). Task 4A is part of the Habitat Development Project, which has as one of its objectives the development of environmentally and economically feasible disposal alternatives compatible with the Corps' resource development directive.

2. Marsh development, one of several disposal alternatives involving habitat development, is under intensive laboratory and field investigation within the DMRP. Considerable research involving marsh creation has been conducted by other elements of the Corps of Engineers, Federal and State agencies, and several universities and private firms. The purpose of this report was to identify those marsh development studies not being conducted by the DMRP and to categorize these projects on the basis of location, size, species composition, status, and results.

3. The information contained in this report was obtained by identifying those investigators recently involved in marsh creation in the United States and interviewing them in person or by telephone or letter. A standardized information request was used. One hundred and five separate projects were identified. The contractor, Dr. E. W. Garbisch, compiled the findings of this survey and has presented a synthesis in both tabular and expository form. Responses received to the questionnaire are appended in microfiche.

4. The reader should note that many of the data presented were derived from observations and are not necessarily the result of planned experimental tests. Examples of subjects that are not completely understood include the need for fertilization and the relative desirability of seeding versus sprigging. Consequently, the application of the findings of this study must be tempered with judgement based on local experience or conditions.

5. This work unit (4A25) provides a current summary and synthesis of non-DMRP marsh development research. Data from these studies will be combined with the findings of DMRP research including the following: identification of relevant criteria and survey of potential application sites for artificial habitat creation (4A01); state-of-the-art survey and evaluation of marsh plant establishment techniques (4A03); productivity of minor marsh grass species (4A04 and 4A20); modeling of ecological succession and production in estuarine marshes (4A05); concept development and economic and environmental compatibility analyses of underwater and/or floating dredged material retaining and protective structures (4A07); development of guidelines for material placement in marsh creation (4A08); heavy metal uptake by marsh grasses (4A15); prediction of a stable elevation for marshes created on dredged material (4A16); establishment of marsh grasses on dredged material (4B06); review and examination of disposal-area filling techniques and rates to identify nonconflicting wildlife enhancement alternatives (5B04); and field studies at Branford Harbor, Connecticut (4A10), James River, Virginia (4A11), Buttermilk Sound, Georgia (4A12), Bolivar Peninsula, Texas (4A13), Dyke Marsh, Virginia (4A17), San Francisco, California (4A18), Apalachicola, Florida (4A17), and Miller Sands, Oregon (4B05). These studies will be used in the development of synthesis reports on marsh productivity and succession on dredged material (4A22), the engineering and economic considerations of habitat development (4A23), and marsh plant establishment on dredged material (4A24).

JOHN L. CANNON
Colonel, Corps of Engineers
Commander and Director

Unclassified

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18. SUPPLEMENTARY NOTES

Appendix B, "Completed Information Request Forms," was reproduced in microfiche and is enclosed in an envelope in the back cover of this report.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Marshes

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Information on deliberate marsh establishment work that is planned, underway, or completed throughout the contiguous United States within the period of 1970-1976 has been identified through (1) literature review, (2) interviewing people who, during the period of May 1975 through January 1977, have become known to be potential sources of pertinent information, and, (3) the completion of distributed information request forms by various correspondents.

Excluding U. S. Army Engineer Waterways Experiment Station (WES) projects currently undeway, marsh establishment projects at 105 district locations have

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) been completed for at least 1 year and 14 projects are planned for the immediate future. Out of the 105 completed or continuing marsh establishment projects, nine were totally unsuccessful (due to vandalism, Canada geese eat-out, wave exposure too severe for seeding, or site surface elevations too low for seeding). Variation encountered in projects included 18 that existed in freshwater or nearly freshwater locations, 68 that existed on the east coast, 17 on the gulf coast, 8 on the west coast, and 12 inland. Fifty-nine were purely experimental, as opposed to applied or partly so.

From information received and collated, practical guidelines for site preparation, marsh establishment, and site management and maintenance were developed and are discussed herein. The two most important factors found for preparing a site for marsh establishment were surface slopes and surface elevations. Within the tidal zone, surface slopes should be developed such that they exhibit reasonable stabilities in the absence of vegetative cover. Surface elevations must be carefully considered in the design and planning of a project and tied in with the various zones of marsh types existing in the region. Surface elevations are most important and their acceptable tolerances most stringent in areas subject to tidal amplitudes of 2 ft or less. Long-term consolidation of fine sediment types is not considered of practical importance in achieving final surface elevations within acceptable tolerances. Close coordination between the site preparation and the marsh establishment stages of a project in terms of time of year is considered important; however, the use of nursery plant stock may alleviate the consequence of unacceptable marsh establishment because of unavoidable delays in the site preparation.

All aspects of marsh establishment must be an integral part of the design and planning of the total project. Selection of the plant species to be used in the various available elevation zones at the site must be governed by (1) the plant species known to exist within these zones in natural marshes in the region, (2) the objectives of the project, (3) the relative growth rates and sediment stabilizing capabilities of the candidate plants, and (4) the relative food value ratings of the candidate plants stock that can be successfully used at the site will depend upon (1) the available surface elevations at the site, (2) the exposure of the site to various physical stresses, and (3) the time of planting.

Properly developed nursery stock is considered superior to all other types for sites or sections of sites subjected to high wave and debris deposition stresses and for summer, fall, and winter plantings. Marsh establishment by seeding is considered feasible only in the spring, in sheltered or confined areas, and at elevations above mean tidal level (MTL) (preferably the upper 20% of the mean tidal range). Although exceptions are discussed, a rule of thumb is that increasing the maturity of nursery transplant materials upon decreasing the elevations in the tidal zone will lead to the greatest survival of transplants and the best overall plant establishment. Transplant spacing and fertilization requirements are discussed. Although fertilizations should be conducted for all marsh establishment work in sand sediments, the need for such fertilizations in other sediment types (silt-clay) is not readily determined.

Three principal maintenance and management requirements for marsh establishment determined by the study are (1) removal of debris and litter depositions, (2) protection against waterfowl depredation, and (3) fertilization. During the growing season, particularly for late spring and summer plants, algae, submerged aquatic plants, free-floating aquatic plants, and/or sundry debris that have been washed and deposited throughout the developing marsh, may have to be periodically removed. Otherwise, the affected plants may be seriously impaired. Depending upon the prevailing populations of geese, and to a lesser extent other wildlife, marsh establishment sites may have to be protected by enclosures or other effective devices. Areas of marsh establishment sites subject to extended periods of high wave stress may require annual maintenance fertilizations to prevent the marsh from succumbing to the stress.

THE CONTENTS OF THIS REPORT ARE NOT TO BE USED FOR ADVERTISING, PUBLICATION, OR PROMOTIONAL PURPOSES. CITATION OF TRADE NAMES DOES NOT CONSTITUTE AN OFFICIAL ENDORSEMENT OR APPROVAL OF THE USE OF SUCH COMMERCIAL PRODUCTS.

PREFACE

The work described in this report was performed under Purchase Order DACW39-75-M-4215 between the U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Mississippi, and Environmental Concern, Inc., St. Michaels, Maryland. The study was sponsored by the Office, Chief of Engineers (DAEN-CWO-M), under the Civil Works Dredged Material Research Program (DMRP).

The research was conducted by Dr. E. W. Garbisch, Jr., during the period from June 1975 to January 1977. This report was prepared for the Habitat Development Project (Dr. Hanley K. Smith, Manager) under Work Unit 4A25, which is part of Tasks 4A: Marsh Development under the general supervision of Dr. John Harrison, Chief, Environmental Effects Laboratory (EEL). Dr. Luther F. Holloway of EEL monitored the study.

COL G. H. Hilt, CE, and COL J. L. Cannon, CE, were Directors of WES during the period of this purchase order, and Mr. F. R. Brown was Technical Director.

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CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
inches	0.0254	metres
feet	0.3048	metres
miles (U. S. statute)	1.609344	kilometres
acres	4046.856	square metres
cubic yards	0.7645549	cubic metres
ounces (U. S. fluid)	29.57353	cubic centimetres
pounds (force) per acre	0.000112	kilograms per square metre
miles (U. S. statute) per hour	1609.344	metres per second

INTRODUCTION

Deliberate marsh establishment is a relatively new process that is of particular interest to the U.S. Army Corps of Engineers because it may occasionally offer an environmentally attrative alternative for the disposal and the use of dredged material. The adoption of marsh establishment as an integral component of federal maintenance dredging projects has been encouraged by Sec. 150 of the Water Resources Development Act of 1976. Section 150 specifically allows potential funding to plan and establish wetland areas as part of any water resources development project that is authorized by the Chief of Engineers.

A recent survey and evaluation of marsh plant establishment by Kadlec and Wentz (1974) uncovered few reports dealing with either natural or deliberate establishment. Concurrent with and subsequent to this survey, sufficient new marsh establishment work has either been completed, initiated, or planned so as to warrant updating existing knowledge, particularly that which would be of practical value to those designing and executing new marsh establishment projects.

The objectives of the work reported herein are (1) to identify, collate, and evaluate information on all marsh establishment work that is planned, underway, or completed throughout the contiguous United States within the time frame of 1970-76, (including earlier work that was not included in the survey by Kadlec and Wentz (1974)), and (2) to provide practical recommendations and guidelines, based on current information, for site preparation, marsh establishment, and site management and maintenance that may be useful in the design and planning phases for any new marsh establishment project.

The coastal zones and inland waterways throughout the United States present such varied project site characteristics that it is impractical to believe that broad guidelines for marsh establishment can ever be developed and confidently applied. Marsh establishment projects must be designed site-specifically using available guidelines to an extent that can be justified.

The Dredged Material Research Program (DMRP) at the U.S. Army Corps of Engineers Waterways Experiment Station (WES) has been intensively studying marsh establishment on dredged materials since 1973. As this report is being prepared for WES, the scope of work did not include a review of its projects. Existing WES projects are listed in Table 1, but specific results of the work to the extent that they are available have not been considered in this report.

A marsh, in this report, is considered to be a community of emergent aquatic plants existing under natural conditions. The results of work on the establishment of submergent communities of aquatic plants, commonly known as seagrasses, baygrasses, or rivergrasses, are not considered herein. Additionally, the establishment of a marsh is considered to be equivalent to the establishment of a desired community of emergent aquatic plants on sediments having appropriate elevations relative to the regional water table or tidal range (Garbisch and Coleman 1977). The colonization of the new marsh by compatable communities of benthic invertebrates and the utilization of the new marsh by wildlife appear to accompany vegetative establishment (Environmental Concern Inc., pers. comm.; Cammen, Seneca, and Copeland 1974; Garbisch, Woller, and McCallum 1975a, b; San Francisco District CE 1976); however, there may be some contention as to when the functions of an established marsh become equivalent to those of a natural one. When the referenced natural marsh has the same (1) age of plant development, (2) sediment composition, (3) water salinity, and (4) exposure as the established marsh, such contention would be negligible.

METHODS

Although a survey of current (1974-76) reports on marsh establishment work was made, much of the work that is planned, in progress, or completed has not been formally reported. Unreported and current information was acquired by personal interviews (visit, letter, or phone) with people who, during the period of May 1975 through January 1977, have been identified as potential sources of marsh establishment information. Additional information was obtained from those correspondents who completed and returned information request forms. A list of the names, addresses, and telephone numbers of all correspondents is given in Appendix A and the completed forms are collected in Appendix B.

Several correspondents in North Carolina and in Florida were unwilling to meet or to transmit unpublished information of their work. All other correspondents freely transmitted results and opinions. Certainly, some important work in marsh establishment has been omitted; however, it is felt that this report reflects a reasonably accurrate overview of the field through 1976.

HISTORICAL PERSPECTIVE

Serious freshwater and brackish water marsh establishment work that was related to wildlife habitat development, improvement, and management began in the United States around the turn of the century. This work, which has been reviewed by McAtee (1939) and Martin and Uhler (1939), was qualitative and poorly documented by modern scientific standards. Yet it provides practical information related to marsh establishment that continues to guide management practices in State and Federal wildlife areas and in private hunting areas throughout the country. Such practices, however, have not been documented well.

Reports of new work on marsh establishment were not available for some thirty years at which time Statler and Batson (1969) and Statler (1973) described the results of transplanting salt marsh plants in South Carolina, and the USDA Soil Conservation Service (1968) provided preliminary guidelines for abating shore erosion through marsh establishment. The Soil Conservation Service has continued its work and interest in the application of marsh establishment for shore erosion control (Sharp and Vaden 1970), although such work has yet to receive broad public acceptance.

At the same time, the U.S. Army Corps of Engineers Coastal Engineering Research Center (CERC), various regional CE Districts, Environmental Concern Inc., Department of Commerce (NOAA), and the North Carolina Coastal Research Program initiated both research and the application of the intentional establishment of salt marsh on dredged and fill materials for new habitat development (Woodhouse, Seneca, and Broome 1972, 1974; Broome, Woodhouse, and Seneca 1974; Eleuterius 1974; Terry, Udell, and Zarudsky 1974; Garbisch and Woller 1975; Garbisch, Woller, and McCallum 1975a, b, c; Kinch 1975; Dunstan, McIntire, and Windon 1975; and San Francisco District CE 1976); and CERC, the Omaha District CE, the Florida DNR, several organizations in Florida, and Environmental Concern Inc. pursued marsh establishment for shore erosion control (Savage 1972; Woodhouse, Seneca, and Broome 1974, 1976; Carlton 1974; Stanley and Hoffman 1974, 1975; Garbisch, Woller, and McCallum 1975a; Garbisch 1976, 1977; Dodd and Webb 1975; Teas, Jergens, and Kimball 1975; and Webb and Dodd 1976). Currently, there are available guidelines for material placement in marsh establishment (Johnson and McGuinness 1975), criteria for new marsh-island site selections (Coastal Zone Resources Corp. 1976), planting guidelines for marsh development (Darovec et al. 1975, Knutson 1977), specifications for marsh plant establishment and guidelines for new marsh site suitability (Environmental Concern Inc. 1976), and standards and specifications for tidal bank stabilization (Soil Conservation

Service 1975).

All of the recently reported marsh establishment work has been conducted in tidal saline waters with the exception of two tidal freshwater projects (Ristich, Fredrick, and Buckley 1976; Garbisch and Coleman 1977) and one inland freshwater project (Stanley and Hoffman 1974, 1975). Two of the five WES marsh establishment projects that are currently underway are in freshwater locations (Smith, pers. comm.). CERC is currently pursuing marsh establishment work at a low salinity location in North Carolina (Knutson, pers. comm.), and Environmental Concern Inc. is continuing freshwater marsh establishment work in the northern reaches of the Chesapeake Bay.

DISCUSSION

All identified (reported and unreported) marsh establishment projects that have been completed, initiated, and planned from 1970 through 1976 are collected in Tables 1 and 2. The names and addresses of all of the people with whom the principal investigator corresponded are given in Appendix A. Salient aspects of many of the tabulated projects are given in the returned questionnaire forms (Appendix B). All of the following statements not referenced or that are noted (Environmental Concer Inc., pers. comm.) reflect the opinions of the principal investigator.

(1) Guidelines for Site Preparation.

Little information was obtained from the correspondents concerning requirements for site preparation. However, from reported work (Woodhouse, Seneca, and Broome 1972, 1974, 1976; Garbisch and Woller 1975; Garbisch, Woller, and McCallum 1975a, 1975c; Garbisch 1976; Garbisch and Coleman 1977), it is clear that the two most important factors in preparing a site for marsh establishment on dredged or fill materials (sloped shores, slopes

Table 1. Recent WES marsh establishment projects conducted throughout the contiguous United States.[a]

Institution	Project Identification and Location	Date	Site Conditions[b] (tidal amplitude, ft)	Plant Species[c]	Plant Stock[d]	Project Design[e]	Project Status[f]	Questionnaire Form No.
EAST COAST								
Town of Huntington, Dept. of Environmental Protection	Wetlands Restoration, ten project locations in Long Island Sound near Huntington, NY	1974-76	SW; N except R at one site; combinations of P, S, & M (7.4)	SA, SP	NP	appl	9-active 1-inactive	1
Town of Islip, Dept. of Environmental Control	Sand Island, in Great South Bay near Islip, NY	1974-	SW, U, S	SA	N from NP	exp & appl	active	2
	East Islip Marina, East Islip, NY	1974-75	FW (pond), U, S	TL, Sa	P	appl	active	3
Boyce Thompson Inst. for Plant Research	Transplantation of *Typha* at Camp Smith, NY (Hudson River mile 44)	1971-73	5 ppt SW, R (2.9)	TA	BR	exp plot	active	g,h
Town of Hempstead, Dept. of Conservation & Waterways	North Line Island, near Point Lookout, NY	1974-76	SW, U, S (3.6)	SA	NP	appl	active	4
Town of Hempstead, Dept. of Conservation & Waterways & the Marine Sciences Research Center SUNY	North Line Island, near Point Lookout, NY	1973	SW, U, S-M (3.6)	SA	P, S, NP	exp	active	g,i
New York District	North Line Island, near Point Lookout, NY	1976	SW, U, S-M (3.6)	SA	S	exp	inactive[i]	g,i
U.S. Dept. of Interior, National Park Service	Plum Beach, Brooklyn, NY	1976	SW, R, O (≈ 3)	SA	S	appl	active[j]	g,k
Environmental Concern Inc.	San Domingo Creek near St. Michaels, MD, in mid-Chesapeake Bay	1971	SW, C, S-M (1.4)[l]	SA, SR, TA, PC, JR	P	exp	active	g
	Hambleton Island (quarry fill), near St. Michaels, MD, in mid-Chesapeake Bay	1972	SW, U, S (1.4)[m]	SA, SP, SC, TL, TA, PC, Sa, SR, SO, JR, DS, PV, AB	N, S	exp & appl	active	5

(Continued)

Table 1 (continued)

Institution	Project Identification and Location	Date	Site Conditions[b] (tidal amplitude, ft)		Plant Species[c]	Plant Stock[d]	Project Design[e]	Project Status[f]	Questionnaire Form No.
Environmental Concern Inc. (continued)	Hambleton Island (natural shore), near St. Michaels, MD, mid-Chesapeake Bay	1973-74	SW, N, S	(1.4)	SA, SP	N	exp	active	6
	Hambleton Island (natural shore, silt & clay) near St. Michaels, MD, in mid-Chesapeake Bay	1972	SW, N, M	(1.4)	SA	N	appl	active	7
	Hambleton Island (dredged material) near St. Michaels, MD, in mid-Chesapeake Bay	1973-75	SW, U, S-M	(1.4)	SA, SC	N	exp	active	8
	Rich Neck, eastern shore of mid-Chesapeake Bay	1973-74	SW, N, S	(1.2)	SA, SP, DS, AB	N	exp	active	9
	Tred Avon River, eastern shore of mid-Chesapeake Bay	1973-74	SW, N, P-5	(1.4)	SA, SP, DS, AB	N	exp	active	10
	Long Point Island, eastern shore of mid-Chesapeake Bay	1973	SW, N, S-M	(1.5)	SA	N	exp	active	11
	Sand Spit, eastern shore of mid-Chesapeake Bay	1973	SW, N, S	(1.5)	SA, SP, SC, PC, PV	N	appl	active	g
	Susquehanna Delta, upper Chesapeake Bay	1973	FW, N, S	(1.7)	SA, Sa, SO, SR, SC, TA, TL, PV	N, S, BR	exp	inactive[n]	12
	Tidal Stream Restoration, Ocean City, NJ	1973	SW, R, S, O	(3.7)	SA, SP	N	appl	active	g
	White Stone, VA	1974	SW, N, S-M	(1.1)	SA	N	appl	active	g
	Greenwich Point, Greenwich, CT	1974	SW, R, S-P	(7.4)	SA, SP, SC	N	appl	active	g
	Centerport Beach, Huntington, NY	1974	SW, N, S	(7.4)	SA	N	appl	active	o
	Sloop Channel near Quimby, VA	1974	SW, U, M	(4.0)	SA	S, N	exp, appl	active[p]	13

(Continued)

(2 of 8 sheets)

Table 1 (continued)

Institution	Project Identification and Location	Date	Site Conditions[b] (tidal amplitude, ft)		Plant Species[c]	Plant Stock[d]	Project Design[e]	Project Status[f]	Questionnaire Form No.
Environmental Concern Inc. (continued)	Burton's Bay near Quimby, VA	1974	SW, U, M	(4.0)	SA	S, N	appl	active[p]	14
	Tar Bay, eastern shore of mid-Chesapeake Bay	1974	SW, U, M	(1.3)	SA, SP, DS	S	appl	active	15
	Slaughter Creek, eastern shore of mid-Chesapeake Bay	1974-75	SW, U, S-M	(1.2)	SA, SP, SC, DS, AB, AA	N[q]	exp, appl	active	16
	Eastville, VA, eastern shore of lower Chesapeake Bay	1975,76	SW, N, S	(2.4)	SA, SP, AB	S, N	appl	active[p]	g
	Knapps Narrows, eastern shore of mid-Chesapeake Bay	1975	SW, U, S,	(1.2)	SA	S	appl	inactive[p,r]	g
	Harris Creek, eastern shore of lower Chesapeake Bay	1975	SW, N, S	(1.2)	SA	S, N	exp	inactive[p]	g
	Cober, eastern shore of lower Chesapeake Bay	1975	SW, N, S	(1.2)	SA, SP	N	appl	active	g
	James River near Hopewell, VA	1975	FW, C, S-M	(2.3)	SA, SC, SR, Sa, Pv, PV, PA	S, N	exp, appl	active	t
	Kittery, ME	1975	SW, R, M-O	(8.7)	SA, SP	N	appl	active	g
	Ridge, MD, western shore of mid-Chesapeake Bay	1976	SW, C, M	(1.2)	SA	S	appl	active	g
	Seaford, NY	1976	SW, U, S	(3.6)	SA, SP, DS, PV, PA	S	appl	active[u]	g
	Northeast, MD, upper Chesapeake Bay	1976	FW, N, S, O	(1.9)	Pv, Pc	S, N	exp plot	active	v
	Ray's Point, MD, eastern shore of mid-Chesapeake Bay	1976	SW, N, S	(1.4)	SA, SP	N	appl	active	g

(Continued)

Table 1 (continued)

Institution	Project Identification and Location	Date	Site Conditions[b] (tidal amplitude, ft)	Plant Species[c]	Plant Stock[d]	Project Design[e]	Project Status[f]	Questionnaire Form No.
Environmental Concern Inc. (continued)	Slaughter Creek, eastern shore of mid-Chesapeake Bay	1976	SW, N, S (1.2)	SP	N	appl	active	g
	Virginia Beach, VA	1976	SW, R, M-O (3.4)	SA	N	appl	active	g
Environmental Consultants, Inc.	Virginia Beach, VA	1975	SW, R, M-O (1.5)	SA	P	appl	active	g,w
USDA Soil Conservation Service	Sloped river banks in VA (five sites)	1958	SW, U, S-M	SA, SP, PV	P	appl	active	g,x
North Carolina State University	Snow's Cut, NC	1971	SW, U, S (3.9)	SA	S, N, BR	exp	active	17
	Beaufort, NC	1972	SW, U, S (3.0)	SA	S, BR	exp	active	18
	South Island, NC	1973	SW, U, S (2 - 2.5)	SA	S	exp	active	19
	Pine Knolls Shores, NC	1974	SW, U, S (2 - 2.5)	SA	S, N, BR	exp	active	20
	Six additional locations for preliminary testing & field scale work in NC	1969-73						
CERC	Field Research Facility, Duck, NC	1973-76	2-3 ppt. SW, N, S (1.0)	SA, JR, PC, TL, TA	BR	exp	active	g,y
Skidway Institute	Hell Gate near Ossabaw Sound, GA	1973	SW, U, M (8.1)	SA	P	exp	active	g,z
GULF COAST								
Texas A & M University	East Galveston Bay	1974-76	SW, N, S-M (1.5)	AD, AG, DS, JR, PC, Sa, SO, SR, SA, SC, SS, TG	BR	exp plot	active	g,aa
Marco Applied Marine Ecology Station	Mangrove transplantation on a dredged material island; Marco Island, FL	1972-74	SW, U, M (2.3)	RM, AG	2 - 8 ft trees	exp	active	21

(Continued)

Table 1 (continued)

Institution	Project Identification and Location	Date	Site Conditions[b] (tidal amplitude, ft)	Plant Species[c]	Plant Stock[d]	Project Design[e]	Project Status[f]	Questionnaire Form No.
Florida Department of Natural Resources	Six project locations in Tampa and Sarasota Bays	1969-71	SW, N, S-M (≈ 2)	RM, LR, AG	S, P	exp	active	g,bb
University of Miami	One site near Port Charlotte (west coast) & three sites near Port St. Lucie (east coast)	1974-	SW, N & R, S-M (≈ 2)	RM	BR	appl	active	g,cc
Florida A & M University	Ocklockonee Bay, dredged material island	1973	SW, U, S (2.7)	SA, JR, DS	P	exp	inactive[dd]	g,dd
Gulf Coast Research Laboratory	Seven project locations in Mississippi Sound: Horn Island Pass, Simmons Bayou, Gulf Park Estates Beach, Ocean Springs East Beach, Ship Island, Horn Island, and Petit Bois Island	1973	SW, U, S (1.7)	SA, SP, SC, DS, PC, JR, PR	P, BR, N	exp plot	active	g,ee
WEST COAST								
San Jose State University	Bay Bridge Approach, Grant Ave., Overpass, Oakland, CA	1969-71	SW, U, M (≈ 8)	SF, Sp, DS, GH	P, S	exp	active	22
	Faber Tract, Palo Alto, CA	1971-	SW, C, M (≈ 8)	SF	P	exp	active	22
	Anza Pacifica, Burlingame, CA	1974-	SW, C, M (≈ 8)	SF	P, S, N	exp	active	22
San Francisco Bay Marine Research Center, San Jose State University, San Francisco District	Alameda Creek, Newark, CA	1974-	SW, U, M (≈ 8)	SF, Sp	P, S, N	exp	active	22, 23, 24
San Francisco Bay Marine Research Center	Marsh Establishment for Shore Erosion Abatement, three sites	1976	SW, N, M (6.8)	SF	P	exp plot	active	g,ff
Madrone Associates	Marion County Day School Marsh bordering Corte Madera Bay	1975	SW, N, S (≈ 5)	SF	P	exp	active	g,gg

(Continued)

Table 1 (continued)

Institution	Project Identification and Location	Date	Site Conditions[b] (tidal amplitude, ft)	Plant Species[c]	Plant Stock[d]	Project Design[e]	Project Status[f]	Questionnaire Form No.
INLAND								
University of South Dakota	Twelve project locations on the shorelines of Lake Oahe and Lake Sakakawea Mainstem Missouri River	1973	FW, N, S-M	Pa, PV, PC, DS, TL, SV	S, P	exp	active	g,hh
DMRP projects underway (not covered in the text of this survey)	Windmill Point Marsh Development Site, James River, VA	1975	FW, C, S-M					
	Buttermilk Sound Marsh Development Site, near Brunswick, GA	1975	SW, U, S					
	Bolivar Peninsula March & Terrestrial Habitat Development, Galveston Bay, TX	1976	SW, U, S					
	Pone #3 Marsh Development Site, San Francisco, CA	1976	SW, U, M					
	Miller Sands Island, Columbia River, OR	1976	FW, U, S					

(Continued)

Note: Footnotes are on sheets 7 and 8.

Footnotes to Table 1.

a) Project areas are all 3 acres or less unless otherwise noted.

b) SW = salt or brackish water, FW = freshwater, S = sand, P = pebbles, M = mud, O = high organic or peaty, U = unconfined dredged or fill materials, C = confined dredged or fill materials, N = natural shore, R = restoration of disturbed or destroyed marsh.

c) Major plant species used is underlined. AA = Ammophila arenaria, AB = Ammophila breviligulata, AD = Arundo donax, AG = Avicennia germinans, DS = Distichlis spicata, GH = Grindelia humilis, JR = Juncus roemerianus, LR = Laguncularia racemosa, PA = Panicum amarulum. Pa = Phalaris arundinacea, PC = Phragmites communis, Pc = Pontederia cordata, PR = Panicum repens, PV = Panicum virgatum, Pv = Peltandra virginica, RM = Rhizophora mangle, SA = Spartina alterniflora, Sa = Scirpus americanus, SC = Spartina cynosuroides, SF = Spartina foliosa, SO = Scirpus olynei, SP = Spartina patens, Sp = Salicornia pacifica, SR = Scirpus robustus, SS = Spartina spartinae, SV = Scirpus validus, TA = Typha angustifolia, TG = Tamarix gallica, TL = Typha latifolia.

d) P = plugs taken from neighboring marshes, N = self-produced nursery stock, NP = nursery stock purchased from Environmental Concern, S = seed, BR = bare root or rhizome stock extracted from a natural or man-made marsh (field nursery).

e) "exp" indicates experimental project, "exp plot" indicates an experimental plot design and "appl" indicates nonexperimental with principal objective to establish a marsh.

f) "active" indicates that the project was generally successful and "inactive" indicates that the project was unsuccessful for the reasons referenced.

g) No questionnaire was completed. Contact institution for additional information.

h) Ristich, Fredrick, and Buckley 1976.

i) Terry, Udell, and Zarudsky 1974.

j) The purpose of this project was to test the use of Holdgro, a polypropylene netting with interwoven paper manufactured by Gulf States Corp., in the broadcast seeding of tidal dredged material. After surface seeding, Holdgro was stapled to the treated surface of the dredged material. No fertilizer was applied. No seedlings were found to emerge through the Holdgro and the project was considered unsuccessful. Will and Susykowski (pers. comm.).

k) Seed germinated late and seedling coverage was sparse following the first growing season, Silverstein (pers. comm.).

l) Fill area enclosed by low profile riprap breakwater.

m) The most exposed side (west) of the project area was protected by portable plastic breakwaters.

n) Canada geese depredation during the winter following the first growing season led to complete loss of all established vegetation.

Footnotes to Table 1 (continued)

o) See Site-I in questionnaire No. 1.

p) All seeding work failed.

q) Sprigs of SP, AB, and AA were provided by the SCS Cape May Plant Materials Center.

r) Available elevations were too low (MSL) for seeding to have any promise of success.

s) Depositions of organic debris buried all transplants.

t) New WES habitat development project.

u) The elevations of the 14-acre site were mostly 3-5 ft above mean high water (MHW).

v) Garbisch and Coleman 1977.

w) Birdsong and Levi (pers. comm.).

x) Sharp and Vaden 1970.

y) Herme and Knutson (pers. comm.).

z) Dunstan, McIntire, and Windon 1975.

aa) Dodd and Webb 1975.

bb) Savage 1972.

cc) Teas, Jergens, and Kimball 1975.

dd) Transplants failed to become established probably because the elevations were too low, Coultas (pers. comm.).

ee) Eleuterius 1974.

ff) Knutson (pers. comm.).

gg) Kingsley (pers. comm.).

hh) Stanley and Hoffman 1974, 1975 (pers. comm.).

Table 2. Planned marsh establishment projects in the contiguous United States

Institution	Project Objective
EAST COAST	
The Port Authority of Providence, RI, and the Coastal Resources Center, University of RI [a]	To use Watchemoket Cove as the disposal area for dredged material removed from Providence Harbor and to establish 50+ acres on these materials to mitigate the environmental impacts of dredging. Preliminary design and feasibility studies have been completed and the project currently is on a "hold" status.
Town of Fairfield, CT, Conservation Commission[b]	To restore ≈ 200 acres of former salt marsh of the Pine Creek estuary that was diked some 80 years ago for flood control and that subsequently converted naturally to a monotypic stand of *Phragmites communis*. The restoration design includes salt marsh revegetation by natural processes and controlled burning of *P. communis* after introducing regular tidal action of the area. The project is scheduled for 1977-78.
Town of Islip, NY, Dept. of Environmental Control[c]	To establish salt marsh on confined silt and clay dredged material that has been consolidating for 3 years. Vegetative establishment throughout the dike and the tidal dredged material will be accomplished by transplanting suitable plant stock in 1977.
Environmental Concern Inc.	To restore ≈ 10 acres of salt marsh destroyed through sewer line installations in Manahawkin Bay, NJ, and Portland, ME. The projects will utilize nursery stock and are scheduled for 1977.[d]
	To utilize salt marsh establishment for shore erosion control at five locations in the mid-Chesapeake Bay. Work scheduled for 1977.
GULF COAST	
Tampa Port Authority, Tampa, FL[e]	To establish ≈ 23 acres of salt marsh on confined fine-sized dredged material at Pendola Point in Hillsborough Bay, FL. The project is presently in a "hold" status.

a) Tippie (pers. comm.). Environmental Concern Inc. 1976. Allender, B. M. and C. Roman. 1976.
b) Steinke (pers. comm.); Steinke, T. J. 1974.
c) Brunn (pers. comm.).
d) Work being subcontracted by Cianbro Corporation, Pittsfield, ME, and Environmental Dredging, Inc., Wenonah, NJ 08090.
f) Chula Vista Boat Basin/Wildlife Reserve Draft EIR (UPD #7563-EIR-15 San Diego Unified Port District 1975. Smith, D. D. 1976.

Table 2 (continued)

Institution	Project Objective
WEST COAST	
San Diego Unified Port District[f]	To establish 70 acres of saltmarsh and wildlife reserve on an estimated 100-acre island constructed from mud and sand materials dredged from the Chula Vista small boat basin in San Diego Bay, CA. Project time frame is 2 to 3 years, anticipated starting year is 1978.
The Resources Agency of California, Dept. of Fish and Game[g]	To reestablish 150 acres of salt marsh in Balsa Chica Bay. Tide gates constructed in 1899 led to the destruction of the saltmarsh. After tidal flaws are restored, it is considered that the tidal area will naturally revegetate. The project site is located between the cities of Huntington Beach and Seal Beach, CA. Starting date uncertain.
City of Palo Alto, CA[h]	To restore 200 acres of salt marsh lost as a result of tide gate construction for flood control. After opening the flood basin to tidal influence, it is expected that salt marsh revegetation will take place naturally. Contract negotiations underway, 1977.[h]
Golden Gate, Highway and Transportation District[i]	To restore 120 to 140 acres of diked and filled (dredged material) salt marsh on the Muzzi property in Corte Madera, CA. Dredged material disposal was completed in 1975 and the dikes were breached in June 1976. Seeding and transplanting salt marsh vegetation is planned for 1977.

g) The Resources Agency of California 1974.
h) White and Crowder (pers. comm.).
i) Faber (pers. comm.) and Kingsley (pers. comm.).

of dikes, and natural shores)are (1) surface angles of repose (slopes) and (2) surface elevations. If either or both of these factors are not properly constructed during the site preparation, marsh establishment will be jeopardized.

(a) Slopes. Suitable surface slopes for developed (unnatural) sites that are unprotected or unconfined will be site-specific and will depend on factors such as natural and induced wave and current climates and the physical characteristics of the fill materials. For tidal saline areas, Woodhouse, Seneca, and Broome (1974) suggest developing slopes that are as gentle as practicable without creating ponding of tidal water; Garbisch and Woller (Q 15-8)* recommended slopes between 30:1 (horizontal:vertical) and 15:1 for an exposed site having mounded unstable sandy sediments developed at the hydraulic pipe outfall location; Garbisch, Woller, and McCallum (1975a) indicated that unvegetated mud sediments developed to a slope of 60:1 were stable; Hair and Brunn (Q 2-4) indicated a suitable slope of 25:1 for an exposed sandy sediment site; and Knutson (1977) recommended slopes of 15:1 or less for seeding and for transplanting.

At this time the best recommendation for the tidal zone, including the EHT elevation (the estimated highest tide from storm and/or wind setup), is to design unconfined material (including earthen dike) surface slopes that are as low as practicable without impounding water and not to achieve or exceed slopes that are deemed to be appreciably unstable under normal conditions in the absence of vegetative ground cover. For contract specifications, the upper limit of surface slopes can be calculated by the project engineer or can be estimated from the prevailing slopes of the non-eroding sections of shores at and contiguous to the site (provided that the shore sediments are compatable with those being dredged). Site elevations above EHT can accomodate much steeper slopes (i.e. ca. 3:1) than those

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*Q a-b = Questionnaire No.-page, Questionnaire 15, page 8 (see Table 1 and Appendix B, Appendix B carries corresponding numbers in the upper right-hand corner of each page).

within the tidal zone. Standards and specifications set by the regional Soil Conservation Service should be used as guidelines for high elevation slopes.

Sites developed by hydraulic dredge disposal will generally encounter material mounding at each pipe outfall location. This results from sediment sorting at the outfall with the heavy particles being retained near the outfall location and the fine particles flowing to distances more remote from the outfall location. These mounds may have steeper slopes than acceptable (Garbisch and Woller 1975 and Q 15-8), and will have to be graded as discussed above.

(b) Elevations. Proper surface elevations are essential for successful marsh establishment. The matter becomes critical in areas subject to low tidal amplitudes of less than 2 ft.* For example, a 4-acre marsh establishment project was unsuccessful because the final elevations were developed 3 to 6 in. too low (see Environmental Concern Inc., Knapps Narrows project, Table 1). The permissable tolerance in the final elevations should be clearly specified in the site preparation work contract. The particular marsh plant species that can be established and the plant materials to be planted both depend upon elevation (Woodhouse, Seneca, and Broome 1974, 1976; Garbisch and Woller 1975 and Q 5-6ff; Garbisch, Woller, and McCallum 1975a; Environmental Concern Inc. 1976; San Francisco District CE 1976; Knutson 1977; Garbisch and Coleman 1977).

If at all possible, a person or firm with marsh establishment experience should be consulted in the early stages of a project's design and planning. Physical and biological engineering inputs are required for all marsh establishment projects. If the project involves adding material to a site, the capacity of the site must be compatable with the forecasted volume of material to be added. The capacity of a specific site is a function of the surface elevation of the fill material , which

* A table of factors for converting U. S. customary units of measurement to metric (SI) units can be found on page 5.

in turn dictates the marsh plant species, if any, that can be established. A variance of 4,000 cubic yards of uniformly distributed fill materials at a one-hectare site corresponds to a elevation variance of one foot. This level of variance is acceptable for areas subject to tidal amplitudes of approximately 5 to 10 ft, but is unacceptable for areas subject to lower tidal amplitudes.

Accurate ($\pm$ 0.1 ft) soundings throughout a potential marsh establishment dredged material disposal site should be made during the flood or ebb tide and at times when the water level reaches the high and low fringes of each zone of marsh type in the immediate area. If this is impracticable, accurate soundings should be made by standard methods and referred to MHW, MTL, or mean low water (MLW). These data then can be used in the project design. Prior to fill material disposal, elevation pipes should be established throughout the site to assist the site preparation contractor in determining when the required elevations have been achieved.

Surface elevation considerations are no less important in the design and execution of marsh establishment for restoration and shore erosion control where filling is not required.

The consolidation of fill materials and the settling of these materials into soft and displacable water bottoms will affect the final surface elevations at the site as well as the real capacity (volume) of the site. These engineering estimates, which in themselves are difficult to compute, are complicated by (1) the biological (marsh establishment) assist in consolidation through dewatering of the fill materials and (2) the organic input to the fill materials (approximately 50% of total annual net production of species is found underground - see Q 5-6ff). Of the fourteen marsh establishment projects listed in Table 1 that were conducted on confined or unconfined mud (silt and clay) dredged or fill materials, there was no mention of surface elevation decreases that might be attributed to long-term consolidation following initial site preparation - even in instances where elevations were surveyed (Garbisch and Woller 1975; Garbisch, Woller, and McCallum 1975a,c). Whereas short-term (days) sediment consolidation considerations are important in the design and initial preparation of the site, once surface elevations have been achieved and appear to be stable (within days), long-term (months) sediment consolidation considerations do not appear to be of practical importance. Further information on the practical importance of long-term sediment consolidation for site preparations will be available from current studies conducted by WES (Smith, pers. comm.).

(c) Coordinating Site Preparation and Marsh Establishment. Another important factor in site preparation is that of timing the completion of the site preparation phase of the project so that the marsh establishment phase can proceed on schedule. This is particularly important if vegetative establishment is to be conducted by seeding and sprigging dormant or growing plants. The optimum time for seeding and sprigging is in the spring (March, April, and May) throughout the east and west coasts (Woodhouse, Seneca, and Broome 1976, Environmental Concern Inc. 1976, Knutson 1977); however, more information on this is needed for Mangroves, freshwater marsh species, and saltmarsh species of genera other than *Spartina*.

Unless it is known otherwise, the probability of successfully establishing a marsh by seeding or sprigging in the summer and fall should be judged to be low. One exception is if potted nursery stock is designated for use. Such stock, if appropriately developed, can be successfully planted 12 months of the year (Environmental Concern Inc. 1976), and its use relieves the urgency of closely coordinating site preparation and marsh establishment.

If for any reason marsh establishment is delayed and interim stabilization of the prepared site is judged to be necessary - or for additional stabilization during vegetative development, Hair and Brunn (Q 2-4) recommend the use of Vexar netting stapled to the sediment surface. Other types of temporary protective structures have been used (Garbisch and Woller, Q 5; Seneca, pers. comm; Webb and Dodd 1976; Dodd and Webb 1975; Smith, pers. comm.).

(d) Sediment Types. There is no reported limitation of uncontaminated sediment types to marsh establishment, with the exception of marsh peat sediments. Seneca, Woodhouse, and Broome (1976), Environmental Concern Inc. (pers. comm.), and Garbisch and Coleman (1977) indicate that such sediments can be expected to support poor plant growth and to render high transplant mortalities. Although fertilization assists plant establishment in peaty sediments (Garbisch and Coleman 1977), machine or hand planting on these sediments is difficult. Generally, Environmental Concern Inc. recommends that because of its poor fertility, poor nutrient adsorption capacity, low water exchange potential, high acidity when disturbed and subject to oxidation, and restriction to vegetative spread when in a consolidated state, marsh peat is the least desirable substrate for marsh restoration or development.

There is no compelling reason to consider artifically mixing, layering, or exchanging sediment types in the preparation of a site for marsh establishment unless such work is proposed on marsh peat sediments.

Silt-clay sediments may develop desiccation fissures, particularly if confined without tidal influence for long periods or at the uppermost tidal elevations if unconfined. Such fissures may fill in time (Dunstan, McIntire, and Windon 1975). If the situation is not naturally remedied prior to the planting phase, the sediments would have to be prepared by tillage or other methods.

The principal problem with fine sediment types in marsh establishment work is that they may present the planting contractor with major obstacles in satisfactorily accomplishing his work. This problem cannot be simply resolved during the site preparation phase and must be confronted at the time of marsh establishment.

2. <u>Guidelines for Marsh Establishment</u>.

Marsh establishment at a given site should include the following considerations and actions:

(i) Delineate the various elevations zones (i.e., MLW-MTL, MTL-MHW, MHW-EHT or low, mean, high) at the site and their respective areas.

(ii) Assess the potential exposure of the site to natural and boat-induced wave, litter and debris deposition, suspended coarse sediment, and animal stresses.

(iii) Identify the plant species that are to be assigned to the available elevation zones.

(iv) Identify the types of plant stock that are compatable with the available elevation zones, potential stresses, and the time of planting.

(v) Determine the plant spacings and seeding rates that are required to produce the desired vegetative cover in the allotted time period.

(vi) Determine the need for and the application rate of fertilizer.

(vii) Evaluate the need for future maintenance and wildlife management.

(viii) Identify the planting techniques and labor force to be employed.

(ix) Estimate the cost.

(x) Obtain the plant materials.

(xi) Execute the planting on schedule.

Items i - ix above should be fulfilled during the design and planning phases of a project with the consultation of a qualified person. During site preparation, the planting contractor should examine the site periodically (1) to ensure that the specified elevation zones and grades are being achieved, (2) to assist in resolving unforeseen construction problems that may affect marsh establishment, and (3) to recommend minor preparation improvements that would facilitate marsh establishment, but that would not require change orders to the scopes of work and costs of the various contracts. Such change orders often are unavoidable, but they may cause substantial delays in the development of a project.

(a) Marshscape Architecture. The plant species that are assigned to the various elevation zones that are or will be available at the site should be selected from those that are occupying or are known to occupy these zones in regional natural marshes. There may often be choices to make. For example, should *Juncus roemerianus* and/or *Spartina alterniflora* be established in the MTL to MHW zone of a tidal saltwater site in southeast United States? Should *S. alterniflora*, *S. spartinae*, and/or *Rhizophora mangle* be established in the MTL to MHW zone of a tidal saltwater site in the Gulf Coast? Should *Peltandra virginica*, *Pontederia cordata*, *Scirpus americanus*, and/or *Typha latifolia* be established in the MLW to MTL zone of a tidal freshwater site in the Hudson River? Should *Distichlis spicata*, *Salicornia pacifica*, and/or *S. patens* be established in the MHW to EHT zone of a mid-west coast site?

Such questions should be answered after considering the objectives of the project (i.e., erosion control, development of fish and wildlife habitat, restoration of a marshfill, biological control of water pollution) and the exposure of the site to physical and animal stresses. In general, for unprotected and unconfined sites with fetches of 10 miles or greater, do not plan to establish vegetation below MHW (Environmental Concern Inc. 1976; Knutson 1977). Other methods must be used to protect this area.

When contemplating the use of slow-growing plants such as mangroves (Savage 1972 and et al. 1975), consideration should be given to establishing a uniform cover of a faster stabilizing and a faster growing plant such as *S. alterniflora* with checkerboard transplants of the slow-grower (mangroves) throughout. This will render the protection often needed for the slow-growing transplants until such time that these achieve maturity and displace or remain in association with the faster growing plants (Lewis, pers. comm. and Lewis 1975). Before applying this concept, it should be confirmed from natural or empirical evidence that the slow-growing plant can develop satisfactorily in association with the dominant one. This concept has been applied to freshwater sites (Garbisch and Woller, Q 12 and James-River-near-Hopewell site under Environmental Concern Inc. in Table 1) using *S. alterniflora*. Although *S. alterniflora* normally is not found in tidal freshwater areas, it can be established successfully in such areas. Because of its rapid growth, excellent lateral spread, and superior sediment-stabilizing fine root structure, *S alterniflora* can render stabilization of the site and temporary protection to the co-transplanted freshwater marsh plants until such time that these plants dominate the site.

Another consideration should be made during the assignment of plant species to the respective tide zones. This concerns the values of the plants as food for the wildlife (particularly waterfowl) which are expected to utilize the site. Excessive animal grazing or consumption of underground plant parts on a marsh establishment site can have devasting consequences (Garbisch and Woller, Q 1,4,5,12; Savage 1972; Dodd and Webb, pers. comm.; Kingsley, pers. comm.; Knutson, pers. comm.; Stanley and Hoffman 1974, 1975; Garbisch, Woller, and McCallum 1975a, b; Garbisch and Coleman 1977). Establishing plants having both high and low food values for prevailing wildlife may reduce the necessity to use enclosures or other devices as protection against wildlife depredation (Garbisch and Coleman 1977). Plants selected must be known to naturally occur in association with each other.

The relative food values of aquatic plants for waterfowl have been reviewed by McAtee (1939) and Martin and Uhler (1939). Geese (Canada, snow, blue, and brant) in modest numbers of 10-100 can inflict permanent and widespread damage to both newly established and natural fresh marshes and salt marshes. The rhizomes of *Spartina* spp., *Scirpus* spp., and *Typha* spp. are favorite foods, while *Peltandra virginica*, *Pontederia cordata*, and *Juncus roemerianus* have low food values for geese. Canada geese generally work a marsh by eating out the seaward edge, progressing marshward (or landward). They quantitatively excavate and consume underground rhizomes, generally while floating. Water over the marsh facilitates the excavation process. Consequently, the vulnerability of the desirable plants to goose depredation increases from MHW to MLW. Above MHW, Canada geese will graze marsh and forage plants; however, snow and blue geese continue to consume underground parts.

Muskrats and nutrias may also present initial and continued problems in freshwater and brackish water marsh establishment. Both are large rodents, particularly nutrias. Muskrats prefer underground (particularly during winter months) and nutria prefer aboveground plant parts as food. Muskrats prefer feeding at night while water covers the marsh surface. They will tunnel into marsh areas above MHW. In low populations (i.e., one family of 3 to 5 per hectare), muskrat runs may have a beneficial influence in marsh productivity through the thinning of dense marsh stands and the increasing of water circulation and exchange.

On a 3-acre 5-year-old marsh establishment site (Garbisch and Woller, Q 5) which was planted to nine brackish water marsh species, muskrats exhibited the following plant preferences for food during the first year: S. cynosuroides > Typha spp. and Scirpus spp. > Phragmites communis > S. alterniflora > S. patens > Distichlis spicata. All S. cynosuroides, Typha spp. and Scirpus spp. were eaten out the first year. In subsequent years, muskrats have selectively fed on two established stands of P. communis, even though S. alterniflora occupies ca. 90% of the marsh surface.

The types of plant stock to be recommended for use in marsh establishment must be carefully considered in light of the available surface elevations at the site, the site's exposure, and the time of planting. Because tidal marsh plant materials have been available from only several registered nurseries, much of the reported marsh establishment work has used plugs or bare root extracts from natural or man-made marshes (see Table 1). If such extractions are supervised properly and carried out according to recommendations (Darovec 1975, Knutson 1977), minor damages to the natural marsh resources may result. Although such practices will continue, they are discouraged for large (one hectare or greater) projects in areas where natural sources of marsh plants are not abundant. Even if transplant materials are removed in checkerboard fashion and with care not to denude those sections being excavated, an adverse impact, introduced particularly by work crews, and to a lesser extent by holding containers and various auxiliary equipment (i.e., water pumps for washing plants), cannot be avoided.

The types of marsh plant stock that are recommended for use under the various site exposures and the various planting times are given in Table 3. Recommendations by Knutson (1977) are similar. The use of plant stock obtained from the immediate region of a site or plant stock developed from plant materials

Table 3. Types of plant stock and recommended planting times.

Use	Bare Root Plants Age:[a]			Dormant		Peat-potted Plants Age:[a]			Seeds
	1-month	3-month	Mature	Bare Root Plants	Peat-Potted Plants	3-mo.	5-mo.	7-mo.	
Nursery & Laboratory	X	X	X	X					X
Winter Planting (above MHW or in sheltered areas[b])				X	X				X
Spring Planting:									
a) sheltered areas[b]		X		X		X			X
b) moderately exposed areas[c]			X	X	X		X		
c) exposed areas[d]					X		X	X	
Summer Planting:									
a) sheltered areas[b]						X			
b) moderately exposed areas[c]						X	X		
c) exposed areas[d]							X	X	
Fall Planting:									
a) sheltered areas[b]						X			
b) moderately exposed areas[c]							X	X	
c) exposed areas[d,e]									

a) Seedlings. b) Confined areas or less than 1 mi fetch. c) 1-5 mi fetch. d) 5-10 mi fetch.
e) Don't plant.

harvested (seeds or sprigs) from this region, is preferred to plant stock originating from more remote locations (Woodhouse, Seneca, and Broome 1976). If practicable, the plant stock used at a marsh establishment site should originate from areas within a 100-mile radius of the site.

Nursery stock in the form of properly developed peat-potted transplant material has been found to provide superior performance to all other plant stock for marsh establishment work (Environmental Concern Inc. 1976); however, Woodhouse, Seneca, and Broome (1976) have not corroborated this. The overriding advantage of peat-potted stock over other plant stock is that the former can be used successfully at almost any time of the year (see Table 3). There are not many multi-contractual construction projects that progress without delays of some sort or another. It is safe to assume that all future marsh establishment projects will not have their sites prepared and available for planting in the spring.

Seeding of _S. alterniflora_, _S. foliosa_, _P. virginica_, and _P. cordata_ appears to be limited to elevations above MTL and preferably the upper 20% of the mean tidal range (Woodhouse, Seneca, and Broome 1976; Environmental Concern Inc. 1976; Knutson 1977; and Garbisch and Coleman 1977). As a rule of thumb, increasing the maturity of nursery transplant materials upon decreasing the elevations in the tidal zone will lead to the greatest survival of transplants and the best overall plant establishment. Important exceptions to this rule of thumb occur (1) throughout the litter deposition corridor and (2) at the high elevation zones at sites experiencing tidal amplitudes in excess of five feet. Extensive deposits of litter and other debris often accumulate throughout the spring and storm tide elevations of natural marshes, particularly salt marshes (see Fig. 1). The marsh in this zone, referred to as the litter deposition corridor, is subject to especially damaging effects of such litter depositions. This zone is an ideal location to design and construct tidal creeks in marsh establishment projects. Such tidal creeks not only will

Fig. 1. Litter deposition corridor in a salt marsh.

increase water circulation throughout the marsh and increase the habitat diversity, they will function as depositories for litter and as optimum environments for the rapid decomposition of the litter and the export of the resulting nutrients.

Marsh establishment throughout the litter deposition corridor may be difficult (see Fig. 1); however, if it is attempted, the most mature plant stock available should be used. This zone may often be suitable for the establishment of marsh shrubs (e.g., Iva frutescens and Baccharis halimifolia) and trees (mangroves), provided that the transplant material is sufficiently developed to withstand the litter depositions.

Another problem with marsh establishment throughout the high elevation zone, particularly in areas subject to tidal amplitudes greater than five feet, is one of water stress during periods of drought. Tidal inundation periods in this zone are short and unless adequate rainfall occurs, surface sediments dry during the interim between successive high tides resulting in high mortalities of seedlings and shallow transplants (Dunstan, McIntire, and Windon 1975; Dieterich, Q 1). Such mortalities can be reduced by using mature peat-potted nursery stock which can be planted 7 to 9 inches deep.

Transplanting, seeding (for S. alterniflora), and fertilizing methods and specifications are available (Darovec 1975; Environmental Concern Inc. 1976; Woodhouse, Seneca, and Broome 1976; and Knutson 1977). To achieve vegetative stabilization of the sediments during the first growing season and uniform vegetative cover during the second growing season, recommended transplant spacings vary from 1 to 3 feet, depending upon the conditions at the site and the plant species. The highest density plantings are recommended for critical area stabilization and for areas subject to high physical stresses. A high degree of cover by well-developed plants will discourage the intrusion of Canada geese to the interior of a newly established marsh and restrict their feeding to the readily protected seaward marsh fringe (Environmental Concern Inc. 1976). Consequently, if winter Canada geese populations are known to be high in the region of a site, consideration should be given to maximizing the density of transplants.

There are no available or convenient chemical test methods for the determination of available nitrogen and phosphorus in tidal sediments (Woodhouse, Seneca, and Broome 1976). Consequently, fertilizer requirements for marsh establishment are not readily determined. Fertilizations should be conducted, as prescribed, for all marsh establishment work in sand sediments. Fertilization may make the difference between plants becoming sufficiently established to sustain the winter stresses and plants succumbing to such stresses (Garbisch, Woller, and McCallum 1975a). For other sediment types (silt-clay), the options are (1) to plant and then to top-dress fertilize one to two months later if plant development and pigmentations suggest nutrient deficiencies; (2) side-dress fertilize with a slow release fertilizer at the time of planting; or (3) conduct short-term (2-mo) growth tests using site sediments in order to identify the optimum fertilization rate. For mud (silt and clay) sediments when growth tests have not been conducted, Environmental Concern Inc. (pers. comm.) recommends side-dress fertilization with Osmocote slow release fertilizer at the time of planting:

Plant Material	Formulation	Rate	Time of Planting
seed	18-6-12 (8- to 9- mo release)	600 lb/acre	spring
plugs, nursery stock, sprigs	18-6-12 (8- to 9- mo release)	1 oz (41 g)/ plant site	early spring and winter
plugs, nursery stock, sprigs	19-6-12 (3- to 4- mo release)	1 oz (41 g)/ plant site	late spring, summer & fall

Osmocote fertilizer has been found to provide satisfactory results in freshwater, brackish-water, and saltwater locations.

(b) Maintenance and Management. The three principal maintenance and management requirements for marsh establishment are (1) removal of debris and litter depositions, (2) protection against waterfowl depredation, and (3) fertilization (Environmental Concern Inc. 1976, Knutson 1977). In populated urban areas, vandalism appears to be an additional maintenance problem - people pulling out transplants and netting (Teas, Jergens, and Kimball 1975; Dieterich, Q 1-9; Hair and Brunn, Q 2-8).

During the growing season, marine algae (e.g., *Ulva lactuca* and *Enteromopha* spp.), rooted submerged aquatic plants (e.g., *Ruppia maritima* and *Zostera marina*), free-floating aquatic plants (e.g., *Eichornia crassipes*), and sundry debris may be deposited throughout the litter deposition corridor and at lower elevations of a marsh establishment site (Knutson, pers. comm.; Kingsley, pers. comm.; Environmental Concern Inc., pers. comm.; Dodd, pers. comm.; and Dieterich, Q 1-9). If such deposits are massive, the affected marsh may be smothered and permanently lost. Periodic removal of deposited materials should be accomplished, as required, during the first growing season. Initially, biweekly site maintenance trips should be made. Depending upon the need, the frequency of maintenance trips can be subsequently adjusted. Late spring and summer plantings are more vulnerable towards litter depositions than are early spring plantings, and may require more frequent maintenance.

Depending upon the design of the marsh establishment project, and often unavoidably, standing crops of the established and neighboring marshes will become naturally harvested and collect throughout the litter deposition corridor during the winter and early spring months (this appears to be more of a problem for salt marshes than for fresh marshes). This litter should be removed before the marsh resumes growth the following spring. Continued annual spring maintenance would be desirable, but generally would not be practicable.

The annual standing crops on sheltered or confined salt-marsh establishment sites may neither be exported nor be relocated, but slump to the marsh surface suffocating new growth and markedly lowering the marsh productivity the following year (Garbisch and Woller, Q 8-9). This is a maintenance problem that is not easily resolved for large-scale projects, unless controlled burning is feasible and is considered desirable.

If large populations of wintering or migrating geese are known to utilize the region where a marsh establishment site is located, measures to protect the site against excessive depredation should be considered (see Section 2(a)). Low cost enclosures have been found to be effective (Environmental Concern Inc. 1976); however, periodic maintenance of these may be required and such protection may be judged to be necessary for several years or more.

Geese are not the only wildlife despoilers in marsh establishment. Cattle have led to serious management and maintenance problems (Stanley and Hoffman 1974, 1975; Sharp and Vaden 1970); horseshoe crabs (Savage 1972) and blue crabs (Garbisch and Woller, Q 5-10) have destroyed plantings; rabbits (Dodd and Webb, pers. comm.) and possibly coots (Knutson, pers. comm. and Kingsley, pers. comm.) have inflicted notable damage to new plantings in the gulf and west coasts; various insects and crustaceans have caused serious problems in the establishment of Rhizophora mangle (Carlton 1974; Kinch 1975 and Q 21-9); and grasshoppers and crickets have been found to cause serious damage to the seedheads and marked reductions in seed productions of established Spartina salt marshes that abut terrestrial habitats (Environmental Concern Inc. pers. comm.; Newton, pers. comm.). Enclosures can be used effectively to exclude cattle from marsh establishment sites (Stanley and Hoffman 1974, 1975); however, effective management of the other mentioned animals has not been developed. Newton (pers. comm.) has suggested maintaining a 3-meter wide barren strip of land between newly established salt marshes and the contiguous terrestrial land in order to discourage grasshopper entry to the marsh.

The necessity for continued fertilizations of established marshes will depend upon the degree of wave stress that they are subject to. Wave stress is a limiting factor for salt marsh (Garbisch and Woller, Q 5-10; Garbisch, Woller, and McCallum 1975a) and fresh marsh (Garbisch and Coleman 1977) establishment. Often the annual fertilizations of areas of established marshes that are subject to high wave stress will make the difference between the marsh enduring or succumbing to the stress (Environmental Concern Inc. 1976). The need for continued fertilization maintenance can be determined through periodic qualitative (visual) comparisons of the productivities of established marshes with those of neighboring natural ones; however, in high wave energy areas, such need should be anticipated.

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